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ИНФОРМАТИКА, ВЫЧИСЛИТЕЛЬНАЯ ТЕХНИКА И УПРАВЛЕНИЕ
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Criteria of evaluating augmented reality applications



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Introduction. The field of augmented reality (AR) is growing rapidly and has great advances in interaction, navigation and tracking. Nowadays there are a lot of trends for AR applications in different areas (education, entertainment, business, medicine, etc.). However, there is a lack of research to provide the evaluating AR apps framework to support developers when creating suitable AR applications for specific needs. We provide a practical approach to quantify some of the AR applications features. We focus on the development of criteria for evaluating augmented reality applications. We discuss the criteria of choosing dimensions for that space such as standards for AR, tools for AR development, navigation and tracking, content management, usability. We provide analysis and evaluation of AR apps through each characteristic using guidelines which we have developed.
Materials and Methods. An AR application is a software application that integrates digital visual, audio and other types of content into a real-world environment. The software quality and performance are the main characteristics of the application, which are key factors for AR applications. The analysis of scientific papers, documents and standards made it possible to determine characteristics that are the most significant quality indicators based on well-grounded users' needs and demands.
Results. The criteria we have developed for evaluating applications with augmented reality enable developers to create their own software products in stages, based on step-by-step requirements for them, evaluating the development process by characteristics. This approach will allow you to create high-quality software products using standardized, modern development tools.
Discussion and Conclusions. In addition, developers will have a detailed understanding of each stage of creating the application and the necessary development tools and technologies to obtain the highest quality result. That will give an opportunity to decide on specific development tools, methods, models and technologies before starting work on a project. As a result, it will provide the final high-quality software product with good extensibility and compliance with the modern requirements of the digital industry market.

Keywords: augmented reality, software development kit, navigation and tracking, content management, usability.

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Критерии оценивания приложений дополненной реальности

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Введение. Дополненная реальность (AR) является быстроразвивающейся отраслью, которая значительно продвинулась в вопросах взаимодействия, навигации и отслеживания объектов. В настоящее время существует множество направлений AR, которые применяются в различных областях (образование, развлечения, бизнес, медицина и т.д.). Однако отсутствуют чёткие критерии оценки фреймворков AR-приложений для поддержки разработки таких приложений под конкретные задачи. В статье предложен подход, позволяющий количественно оценить некоторые характеристики AR-приложений. В данной статье сделана попытка разработки критериев оценки приложений дополненной реальности. Предложены критерии выбора измерений пространства разработки, такие как стандарты для AR, инструменты для разработки AR, навигация и отслеживание объектов,

управление контентом, удобство использования (юзабилити). Предоставлены анализ и оценки AR-приложений по каждой предложенной характеристике.
Материалы и методы. AR-приложение – это программное приложение, которое интегрирует цифровой визуальный, аудио-контент и другие типы контента в реальную среду. Качество и производительность программного обеспечения являются основными характеристиками приложения, которые являются критически важными факторами для приложений AR.
Анализ научных работ, документов и стандартов позволил определить характеристики, которые являются наиболее значимыми качественными показателями, основанными на обоснованных потребностях и требованиях пользователей.
Результаты исследования. Разработанные нами критерии оценки приложений с дополненной реальностью позволяют разработчикам создавать свои собственные программные продукты поэтапно, основываясь на пошаговых требованиях к ним, оценивая процесс разработки по характеристикам. Такой подход позволит создавать высококачественные программные продукты, используя стандартизированные, современные средства разработки.
Обсуждение и заключения. Разработчики будут иметь детальное понимание на каждом этапе создания приложения, что позволит выбирать необходимые инструменты и технологии разработки для получения результата наивысшего качества. Это также даст возможность определиться с конкретными инструментами, методами, моделями и технологиями разработки до начала работы над проектом. В результате будет получен конечный высококачественный программный продукт с хорошей расширяемостью и соответствием современным требованиям рынка цифровой индустрии.

Ключевые слова: дополненная реальность, комплект разработки программного обеспечения, навигация и отслеживание, управление контентом, юзабилити.

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Introduction. The development of the modern market of augmented reality (AR) technology contributes to the emergence of a larger number of AR-applications widely used in industries including healthcare, public safety, gas and oil, tourism and marketing, entertainment and academia. In connection with the increased interest in this technology, the development of functional capabilities of AR projects is also carried out, which stimulates an increase in the needs of AR-technology using in the most diverse sectors of modern society.

Unfortunately, some significant aspects of the AR applications development and implementation and AR services, often ignored for the design simplicity and implementing speed, are the compliance with such systems to real conditions and the evaluating under real operating conditions. To develop successful and highly efficient AR systems that can be adopted in everyday scenarios, user assessment and feedback are very important [1].

Augmented reality is a very young industry, and there are still no generally accepted standards for developing AR applications. Although the main platforms for creating augmented reality applications have been defined: ARKit[1], ARCore[2] and Unity[3] (mostly used) – even now AR applications developed using these tools are available for launch only on a limited type of digital and mobile devices.

The situation is exactly the same with wearable devices, HoloLens and Magic Leap glasses – each manufacturer offers its own unique software for creating augmented reality programs. Experts give several years before the industry consolidates and common standards allow making the development of augmented reality applications accessible and universal for all AR developers.

Rapid progression of the AR field requires effective and validated methods of design evaluation to be developed. Failure to consider the usability of AR applications during the design process will result in an increase in user errors and accidents, limiting user trust of the technology and undermining user perceptions of the technology, for both AR and Virtual Reality (VR) technologies [2].

The authors of the papers [1], [2], [3] provided an overview of the important designing and implementing features of AR applications and proposed theoretical evaluation of AR systems and frameworks through the standardization aspects. Endsley and others [4] described principles of design heuristics for AR for multi-dimensional augmented environments. Some examples of user experience evaluations were presented in the papers [5], [6], [7], [8], [9], [10].

J. L. Gabbard and J. E. Swan [11] proposed a Usability Engineering (UE) for Augmented Reality approach that

[1] Augmented Reality – Apple Developer. https://developer.apple.com/augmented-reality/
[2] ARCore – Google Developers. https://developers.google.com/ar
[3] Unity for all. https://unity.com/

inserts iteratively a series of user-based studies into a traditional usability-engineering life cycle. Several usability testing methods of the AR application (subjective measurement using human perception, objective measure from observation, evaluation by expert through cognitive walkthrough, heuristic evaluation, lab observation, questionnaire) were described by Pranoto and others [12]. Martins and others [13] presented practical use of the usability methods for evaluating an AR children's book with multiple methods. Other aspects of AR technology tools and AR applications evaluating were presented in the papers [14] and [15].

Akgul and others [16] adapted an existing deep learning architecture to solve the detection problem in AR application using camera-based tracking. Other methods that help to improve AR application and to increment the productivity in manufacture were described in [17], [18], [19].

There are several survey papers on AR development, but none is dedicated to Mobile Augmented Reality. Huang and others [20] present the results of the latest technologies and methods survey that improves run-time performance and energy efficiency for the practical implementation of mobile AR applications.

We have presented AR application "Tilsimli arifler" ("Magic letters") and special features of design and developing mobile AR application for enhancing early literacy skills in our papers [21], [22].

Software quality and performance. An AR application is a software application that integrates digital visual, audio and other types of content into a real-world environment. The software quality and performance are the main characteristics of the application, which are key factors for AR applications. Software development is a complex and multi-faceted process, in which a large number of specialists of various areas of expertise and various skill levels participate. In addition, many technical, technological, and managerial issues intertwine in the application development process. The success of the project and the quality of the developed product depend on their adequate involvement.

The analysis of papers, documents (e.g., [2], [3], [10], [16], [22]) and standards (e.g., ISO-IEC JTC 1 SC 24, 18521-1[1], ISO 9000[2]) shows that the following characteristics are the key quality indicators based on well-grounded users' needs and demands:

— inadequate functioning of the software product;

— insufficient interaction of the product with other software, hardware, telecommunications;

— failures of the software application during the intended use;

— the slowed down time of the software product and the delay in the presentation of intermediate and output information;

— incomplete display of information;

— inconsistency of stored data and information entered by the operator;

— loss of relevance of the information;

— violation of the confidentiality of information.

In addition to such "primary" quality data coming directly from the consumer, developers use "internal" indicators to evaluate the parameters of the current project:

— the lines of code in the standard mode;

— the number of detected errors per 1000 lines of code;

— program complexity parameters;

— the probability of occurrence of specific errors;

— the project complexity and cost of a code unit;

— price of a "man-month";

— statistical characteristics of processes (expectation, variance, correlation function, etc.) and other estimated parameters.

Augmented Reality Application Evaluation Criteria. Ten experts with more than 3 years' experience in AR application development help us to create criteria for evaluating AR apps. We divided the main criteria for assessing the quality of augmented reality applications into 5 groups (Fig 1):

— AR app design and Art design;

— Graphic programming;

— AR applications programming;

— Application profiling and optimization;

— Publishing applications (build).

When developing an *AR application design*, we recommend the following characteristics that should be con-

[1] Kim G. Augmented Reality Continuum Concepts and Reference Model – Part 1: ARC Reference Model (Work Item Proposal), ISO-IEC JTC 1 SC 24, 18521-1. 2012.
[2] ISO 9000 Family Quality Management. https://www.iso.org/iso-9001-quality-management.html

sidered:

1. The surface. How the application can adapt to various surfaces. If you use frameworks, you can use the built-in surface detection function. For example, the application can recognize the floor, walls and objects.
2. Shine. Evaluation of illumination is very important for the realism of objects. It is advisable to use dynamic lighting with shadows in real time.
3. Space needed. Users can experience AR in three different sizes: table scale, room scale, and open environment. The user should always have enough space to simply enjoy the experience. Thus, it is necessary to think over this before the user starts using the application. For example, if an application requires an open environment, you need to inform the audience in advance before they start using the product.
4. Single-user or multi-user product. If you are developing a multi-user interface, you should design the product when everyone is involved in the process. It is important to create a sense of audience connection with the product. For example, if you are developing an AR game, you can provide a map that shows the location of users and provides real-time status notifications.

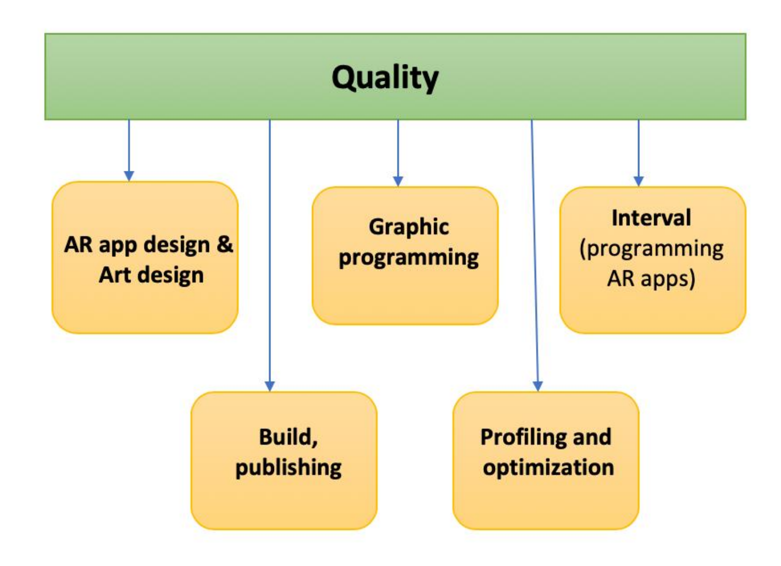


Fig. 1. Evaluation criteria for AR applications

The main criteria are highlighted as follows (Table 1).

Table 1

AR App Design and Art Design evaluation points

AR App Design and Art Design	25
Actual requirements (of the market) in terms of application design	2
Interface design requirements	2
UX features for AR applications	1
Target platform specifications	2
3D modeling principles	1
Principles of work with particle systems	1
Types and features of the creation and use of textures	1
Principles of working with shaders and materials, rendering features	2
Features for customizing models and textures, as well as materials for export to the game engine	1
Create high-quality 3D models in modern editors	2
Create UV-scan in modern editors	2
Texturize models in modern editors	2
Rigging and animating models in modern editors	2
Customize animation in game engines	2
Create and customize shaders, materials in simulation programs and game engines	2

The initial version of Table 1 was proposed by the authors, then it was discussed with ten experts in AR devel-

opment using brainstorming techniques.

To solve the problems of displaying complex graphic objects, it is necessary to develop effective methods and algorithms for processing graphic information at the stages of input, encoding, transformation and image formation. All of this makes up a set of basic computer graphics tasks, so we have identified the main components needed to create a high-quality graphic component (Table 2).

Graphic programming enables to create visual effects through the development of shaders using the functions of graphic libraries, customizing the rendering of the development environment, using effective postprocessing libraries, customizing shadows, and more. All these components make it possible to obtain high-quality images by applying various effects, as well as improve the optimization of application performance.

Table 2

Graphic programming evaluation points

Graphic programming	25
Rendering features on the target platform	2
Using textures and materials in the game engine	2
Features of the work of graphic libraries	2
Principles of rendering geometric objects and images	2
Principles of proper postprocessing	3
Features of implementing lighting and shadows on the used game engine and target platform	3
Configure static and dynamic lighting in the used game engine	2
Optimize rendering processes	3
Customize postprocessing and final image appearance	2
Create procedural geometry using game engine tools	2
Programming the rendering of the frame	2

Evaluation points presented in Table 2 were proposed by the authors and later they were discussed with ten experts in AR development.

During the development of the software part of the mobile application with augmented reality, it is necessary to precisely determine the fundamental development tools, and, accordingly, the programming languages, programming environments, patterns, architecture, etc. This is necessary for a clearer and more coordinated team work, understanding the requirements and tasks, comprehension of the logic and sequence of application development, orientation in the project, reducing risks, and interaction of each team member with each other. To achieve this, we have identified the following points for the programming phase, which should be followed in order to obtain a positive result of the development process (Table 3).

Table 3

AR Applications Programming evaluation points

AR Applications Programming	25
Modern programming languages used in AR development	2
OOP principles	2
Building an application architecture	2
Principles of building AR applications	2
Code design standards	2
Basic math for AR applications	2
Work with a network in the context of AR	2
Work with modern AR application development environments	2
Write high-quality code in modern programming languages used in AR	2
Implement specific application mechanics as soon as possible	2
Use development environments for writing and debugging code	2
Work with necessary SDKs for AR	2
Use collaboration tools	1

The evaluation points presented in Table 3 were proposed by the authors and brainstormed with ten experts in AR development.

When developing applications with augmented reality, it is important to consider the features of application

optimization for PC and mobile devices, as well as the architecture of mobile devices in the context of application optimization. In this regard, we have identified the points that we advise to adhere to during the development in order to achieve maximum optimization of AR applications (Table 4).

The profiler tool provides specific data on game performance and facilitates its optimization process. The profiler provides frame-by-frame metrics with which you can more easily identify problem areas.

Table 4

Application Profiling and Optimization evaluation points

Application Profiling and Optimization	16
Optimization of AR application performance	3
Optimization of 3D objects	2
Geometry optimization	2
Optimization of textures and materials for the target platforms	2
Optimization of the main application processes	2
Optimization of physics in the application	2
Using built-in game engine profilers, as well as external profilers	3

Table 4 was created by the authors and then it was discussed with ten experts in AR development.

After completion of all stages of the application development, it is important to publish the application. The publication represents the release of the application on any platform where the customer (end-user) can easily download the final version of product, get acquainted with it, get all the necessary documentations, technical support and feedback from the developer. Each of the platforms puts forward its specific requirements to the publishing application, which are necessary for correct displaying the application in the platform’s market, obtaining all information about the application’s operation, ensuring end-user security, promoting the application, and more. In this regard, the publication is one of the most important and crucial stage of the development. We have identified several main platforms, before using which it is necessary to familiarize yourself with all the documentation and assembly features for the appropriate platform (Table 5).

Table 5

Publishing applications (build) evaluation points

Publishing applications (build)	9
Features of building an application for Windows	3
Features of the build application for Android.	3
Features of the build application for OS X/ iOS.	3

Evaluation points presented in Table 5 were proposed by the experts in AR development.

Conclusions. Nowadays, the augmented reality is one of the most innovative and a new digital trend in the developing applications for all type of devices. The AR technology opens a new horizon and is going to get more popular in the foreseeable future.

The criteria we have developed for evaluating applications with augmented reality enable developers to create their own software products in stages, based on step-by-step requirements for them. This will allow you to create high-quality software products using the standardized, modern development tools.

In addition, developers will have a detailed understanding of each stage of creating the application and the necessary development tools and technologies to obtain the highest quality result. That will give an opportunity to decide on specific development tools, methods, models and technologies before starting work on a project; and, in the process of working on the basis of existing criteria, gradually create key application stages, with possible subsequent upgrades and improvements. As a result, it will provide the final high-quality software product with good extensibility and compliance with the modern requirements of the digital industry market.

In the follow-up study, we are going to apply this approach for evaluating several AR applications. To thoroughly verify the proposed criteria, additional testing will be required, where more software field experts should be involved. Engaging third-party experts will assess the suitability of the proposed criteria. We believe that this approach will become part of the AR application development process.

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